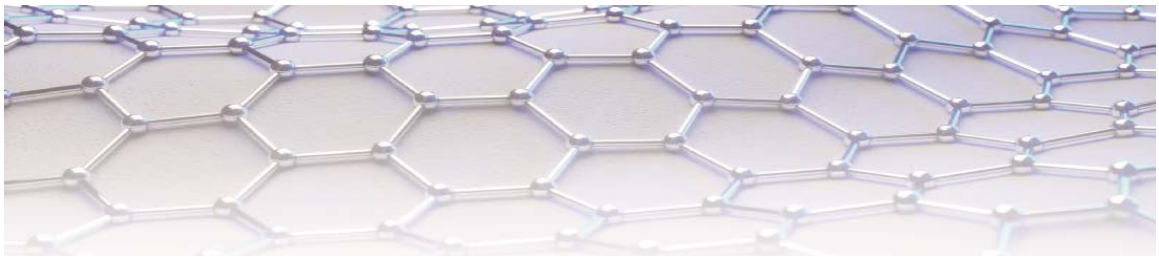


Welcome to the 5th International Workshop on 2D Materials

This event is a part of activities of A3 Foresight Program

"Joint Research on Novel Physical Properties and Functionalities of Emerging 2D Materials and van der Waals Heterostructures"

which will last for five years from August 2018 to July 2023.

The Asia-Pacific region, including A3 countries (Japan, China, and Korea), has come to occupy an increasingly important position in the 2D materials researches. The purpose of this Project is to promote the exchange of young researchers and international collaborations, and to make the A3 countries a world-class center of excellence in the 2D materials science. The previous four A3 workshops have been successfully held in Tokyo, Nanjing, Seoul and Mastue (joint with RPGR).

This year, unfortunately, our A3 activities have been seriously influenced by the global COVID-19 Coronavirus outbreak and the on-site workshop cannot be organized as usual. To keep encouraging the collaborating interaction among the researchers within A3 project, this on-line meeting is proposed to keep our A3 PIs and students communicating with each other. The purpose of this workshop is that all the members can have a stimulate discussions on the forefront of research, share exciting ideas and find further collaboration among A3 PIs.

We sincerely hope that the scope of the workshop will serve the interest of the A3 foresight program and the scientific community. Wish you a stimulating workshop and interactions via this on-line workshop.

Program Leaders

Prof. YUAN Hongtao (Nanjing University)
Prof. IWASA Yoshihiro (University of Tokyo)
Prof. CHEONG Hyeonsik (Sogang University)

国家自然科学基金委员会
National Natural Science Foundation of China

Japan Society for the Promotion of Science
日本学術振興会

A3 Foresight Program

NRF 한국연구재단
National Research Foundation of Korea

Thursday, Jul. 9
Start from 1pm @Beijing time
2pm @Tokyo and Seoul time

Join Zoom Meeting
https://zoom.com.cn/j/8503020726?pwd=ZDZremNobXY1MkRrMjZFNXRmK0VyUT09

Meeting ID: 850 302 0726
Password: Please confirm with Prof. Iwasa, Prof. Cheong or Prof. Yuan.

12:55-13:00	Host Chair: Hongtao Yuan Opening remark 5 min			
1st session	Chair: Yoshihiro Iwasa			
13:00-13:30	Lecture K1	**Observation of exotic many-body exciton in $NiPS_3$**	Je-Geun Park	Seoul National University
13:30-14:00	Lecture J1	**Syntheses and growth mechanisms of 2D materials**	Hiroki Ago	Kyushu University
14:00-14:30	Lecture C1	**Assemble 'new materials' from single atomic layer building blocks**	Lei Wang	Nanjing University
14:30-14:45	15-min Break			
2nd Session,	Chair: Hyeonsik Cheong			
14:45-15:15	Lecture K2	**Topological excitations in van der Waals layers with strong interactions**	Han Woong Yoem	CALDES, Institute for Basic Science
15:15-15:45	Lecture J2	**Patterns and driving forces of charge density wave in transition metal chalcogenides**	Mohammad Saeed	The University of Tokyo
15:45-16:15	Lecture C2	**Photoemission Study of Intrinsic Magnetic Topological Insulator $MnBi_2Te_4$ and $MnBi_4Te_7$**	Zhongkai Liu	ShanghaiTech University
	15-min Break			
16:30-17:30	PI collaboration discussion			

5th International Workshop on 2D Materials

Title of the Presentation: Observation of exotic many-body exciton in $NiPS_3$

First Name: Je-Geun

Last Name: Park

Affiliation: Dept. Physics & Astronomy, Seoul National University, Seoul, KOREA

Email: jgpark10@snu.ac.kr

Short Biography:

Je-Geun Park is a professor of the Department of Physics and Astronomy, Seoul National University, and director of Center for Quantum Materials, National Research Foundation of Korea. He received BSc (1988) and MSc (1990) from Seoul National University, and Ph.D. from Imperial College London (1993), His research covers broad areas of strongly correlated electron systems, including more recent works on magnetic van der Waals materials.

Abstract:

$NiPS_3$ belongs to a class of antiferromagnetic van der Waals materials, and it is one of the first magnetic van der Waals materials to be exfoliated down to monolayer [1]. When it undergoes an XY-type, or more precisely, an XXZ-type ordering below T_N=155 K, there is a drastic spectra transfer in the optical data over a wide energy range, a hallmark of correlation physics at work [2]. More interestingly, it also displays a clear thickness dependence of the magnetic order, which is suddenly destroyed between bilayer and monolayer $NiPS_3$ [3].

More recently, we have undertaken extensive studies of its optical and electronic studies using PL, optical absorption, and RIXS to find that it hosts highly unusual exciton features around 1.5 eV [4]. By carrying out massive many-body calculations, we could identify it as an exciton due to a transition from a Zhang-Rice Triplet to a Zhang-Rice singlet, i.e., a spin-entangled exciton of many-body origin. In this talk, I will discuss several salient features of this recently discovered exciton with a particular reference to the correlation physics.

[1] Cheng-Tai Kuo, et al., Scientific Reports 6, 20904 (2016).
[2] So Yeun Kim, et al., Phys. Rev. Lett. 120, 136402 (2018).
[3] Kangwon Kim, et al., Nature Communications 10, 345 (2019).
[4] Soonmin Kang, Kangwon Kim, Beom Hyun Kim, Jonghyeon Kim, Kyung Ik Sim, Jae-Ung Lee, Sungmin Lee, Kisoo Park, Seokhwan Yun, Taehun Kim, Abhishek Nag, Andrew Walters, Mirian Garcia-Fernandez, Jiemin Li, Laurent Chapon, Ke-Jin Zhou, Young-Woo Son, Jae Hoon Kim, Hyeonsik Cheong, and Je-Geun Park, Nature (in press).

Invited speaker

5th International Workshop on 2D Materials

Title of the Presentation: Syntheses and growth mechanisms of 2D materials

First Name: Hiroki

Last Name: Ago

Affiliation: Global Innovation Center (GIC), Kyushu University, Japan

Email: h-ago@gic.kyushu-u.ac.jp

Short Biography:

Prof. Hiroki Ago received his PhD from Kyoto University in 1997. After staying at Cavendish Laboratory, Cambridge University during 1997-1999, he moved to National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba. In 2003, he moved to Institute for Materials Chemistry and Engineering, Kyushu University as an associate professor. He became a full professor of Global Innovation Center (GIC) of Kyushu University in 2016. His current research focuses on exploring science and applications of nanomaterials, particularly graphene and related 2D materials. He received Iijima Award from the Fullerene-Nanotube Research Society of Japan (2006), Young Scientist Award from the Minister of Education, Culture, Sports, Science and Technology (MEXT), Japan (2008), and Best Paper Award from the Japan Society of Applied Physics (2014).

Abstract:

The development of graphene research has opened the new field of atomically thin, two-dimensional (2D) layered materials. For realizing various applications, it is important to establish synthesis methods of high-quality, large-area 2D materials. We have been studying chemical vapor deposition (CVD) growth of graphene and other related 2D materials, such as transition metal dichalcogenides (TMDCs) and hexagonal boron nitride (h-BN), with the main focus on the understanding of growth mechanisms and the growth of high-quality 2D films for advanced applications. In this talk, I will review our recent work on the highly controlled CVD growth of single- and double-layer graphene, TMDCs, h-BN, and their heterostructures, based on our unique heteroepitaxial approach.

Selected publications:

[1] H. Ago et al., *ACS Nano*, **4**, 7407 (2010).
[2] H. Ago et al., *J. Phys. Chem. Lett.*, **3**, 2228 (2012).
[3] Y. Takesaki et al., *Chem. Mater.*, **28**, 4583 (2016).
[4] H. Kinoshita et al., *Adv. Mater.*, **29**, 1702141 (2017).
[5] K. Suenaga et al., *ACS Nano*, **12**, 10032 (2018).
[6] Y. Uchida et al., *ACS Nano*, **12**, 6236 (2018).
[7] Y. Miyoshi et al., *Nat. Commun.*, **9**, 1279 (2018).
[8] H. Nakajima et al., *Sci. Adv.*, **5**, eaau3407 (2019).
[9] H. G. Ji et al., *Adv. Mater.*, **31**, 1903613 (2019).
[10] P. Solís-Fernández et al., *ACS Nano*, DOI: 10.1021/acsnano.0c00645

Invited speaker

5th International Workshop on 2D Materials

Title of the Presentation: Assemble 'new materials' from single atomic layer building blocks

First Name: Lei

Last Name: Wang

Affiliation: Physics department, Nanjing University, China

Email: LeiWang@nju.edu.cn

Short Biography: Dr. Lei Wang is a professor in Physics department, Nanjing University. He received the B.S. (2005) in Electrical Engineering from National University of Singapore. In 2014, he earned a Ph.D. in Electrical Engineering at Columbia University, where he studied the electronic transport properties of the atomically thin two-dimensional (2D) materials. In particular, Dr. Wang developed the novel 'pick-up' transfer and edge-contacting technique to achieve 2D material devices in an ultra-clean limit in 2013. These methods also establish a platform to assemble the van der Waals heterostructures layer by layer for device applications in multiple research directions. Between 2015 and 2019, he won the Kavli postdoctoral fellowship at Cornell University, where he has been exploring 2D materials-based unconventional electronics tuned by their topological property changes.

Abstract:
As the conventional silicon electronic devices reach the dimensional scaling limit for better performance, other candidates like spintronics, quantum computing, tunneling transistors and valleytronics on new material systems are intensively being explored for possible future electronics. Two-dimensional (2D) material is one of the important platforms for these novel systems. Although 2D materials such as graphene are promised to carry remarkable electronic performance, there are still two technical barriers, reducing channel disorders and achieving better contact resistance. I will present the techniques I developed to controllably sandwich different 2D materials, which dramatically reduces disorder to their theoretical limit [1]. I will also discuss about how to achieve the lowest electrical contact resistance to the fully encapsulated atomic layers. In addition, these new techniques allow us to stack different 2D materials together layer by layer to form heterostructures, with controlling their positions, thickness, and lattice mismatch angles. I will talk about how to tune these nobs to achieve the band structure engineering [2] at the interfaces between the different atomic planes and, in the sense, creating 'new' materials from these basics single atomic building blocks[3,4].

[1] L. Wang et al, Science, 614-617 (2013).
[2] C. Dean, L. Wang et al, Nature 497, 598-602 (2013).
[3] L. Wang et al, Science 350, 1231-1234 (2015).
[4] L. Ju, L. Wang et al, Science 358, 907-910 (2017)

Invited speaker

5th International Workshop on 2D Materials

Title of the Presentation: Topological excitations in van der Waals layers with strong interactions

First Name: Han Woong

Last Name: Yeom

Affiliation: CALDES, Institute for Basic Science, Pohang, Korea

Email: yeom@postech.ac.kr

Short Biography: Professor Han Woong Yeom graduated from Seoul National University, Korea and got his PhD degree in Tohoku University, Japan in 1996, for his photoelectron spectroscopy study of low dimensional electronic states on semiconductor surfaces. He worked as a faculty member in the University of Tokyo, Japan, Yonsei University, Korea, and now is serving for POSTECH, Korea. His research has focused on low dimensional electronic systems fabricated in atomic scale on solid surfaces. He has pioneered the field of 'metallic atomic wires,' a new class of one-dimensional materials, in particular, by discovering a series of phase transitions for those self-assembled wire on silicon surfaces. His recent research focuses on topological excitations of such atomic wires and prototype 2D charge density wave systems such as TaS_2 and $NbSe_2$.

Professor Yeom received important awards in Japan and Korea including Young Researcher of the Year of Japanese Society for Synchrotron Radiation Researches in 2001, Academic Achievement Award of Korean Physical Societies in 2007, Korean Science Award in 2015, Inchon Prize for Science in 2016, and Kyong Am Prize for Science in 2017. Professor Yeom has coauthored more than 200 journal articles. He is a fellow member of Korean Physical Society, American Physical Societies, and Korean Academy of Science and Technology.

Abstract:

Manybody interactions within low dimensional electronic system often induce symmetry-breaking phase transitions into states such as charge-density wave and superconductivity. The broken symmetry brings about degenerate states which are necessarily connected by topological excitations such as solitons, domain walls, and vortices. These local excitations have unusual properties, which can govern the macroscopic properties of the electronic system and deliver extra functionality. In this talk, I review my recent research activity for domain wall topological excitations in strongly-interacting charge-density-wave systems of transition metal dichalcogenides such as TaS_2 and $NbSe_2$. The detailed atomic, electronic, and topological structures of a variety of domain walls are disclosed and understood. The physics and functionality emerging from individual and networked domain walls are discussed.

[1] D. Cho *et al.*, Nat. Commun. **7**, 10453 (2016).
[2] D. Cho *et al.*, Nat. Commun. **8**, 392 (2017).
[3] J. H. Park, G. Y. Cho, D. Cho, and H. W. Yeom, Nat. Commun. **10**, 4038 (2019).
[4] G. Gye *et al.*, Phys. Rev. Lett. **122**, 016403 (2019).
[5] G. Gye *et al.*, to be submitted.

Invited speaker

5th International Workshop on 2D Materials

Title of the Presentation: Patterns and driving forces of charge density wave in transition metal dichalcogenides.

First Name: Mohammad Saeed

Last Name: Bahramy

Affiliation: Department of Applied Physics, The University of Tokyo, Tokyo, Japan

Email: bahramy@ap.t.u-tokyo.ac.jp

Short Biography:

Mohammad Saeed Bahramy received his PhD from the department of materials science and engineering at Tohoku University in 2007. After serving a JSPS post-doctoralship at Tohoku University (until 2010) and later a special postdoctoral fellowship at RIKEN (until 2013), he was appointed as a lecturer at the University of Tokyo's department of applied physics (UT-DAP; until 2020). He is currently a Senior Chief Scientist at UT-DAP. His research mainly focuses on the first-principles study of topological quantum phenomena, two-dimensional materials, low dimensional magnetism, strongly correlated electron systems, and superconductivity.

Abstract:

Charge density wave (CDW) is one of the most common, yet least understood, quantum phenomena in condensed matter physics. Occurring in metallic systems, it forms a new ordered state with a distorted lattice structure and modulated charge density distribution. Astonishingly, these modulations emerge in various patterns with disparate dimensional charactersitics, even within the same family of materials. In this talk, I propose a general framework [1], that helps us to unify distinct trends of CDW instability. To show this, I focus on an isoelectronic group of transition metal dichalcogenide, 2*H*-*M*X2 (*M*=Nb, Ta and *X*=S, Se) which are best known for their puzzling CDW orderings. For example, while NbSe2 exhibits a strongly enhanced CDW order in two dimensions, TaSe2 and TaS2 behave oppositely, with CDW being absent in NbS2 entirely. Combining Raman scattering spectroscopy with first-principles calculations, I show that such a disparity arises from a competition of ionic charge transfer, electron-phonon coupling, and electron correlation. Despite its simplicity, the approach presented here, in principle, explain dimensional dependence of CDW in any material, thereby shedding new light on this intriguing quantum phenomenon and its underlying mechanisms.

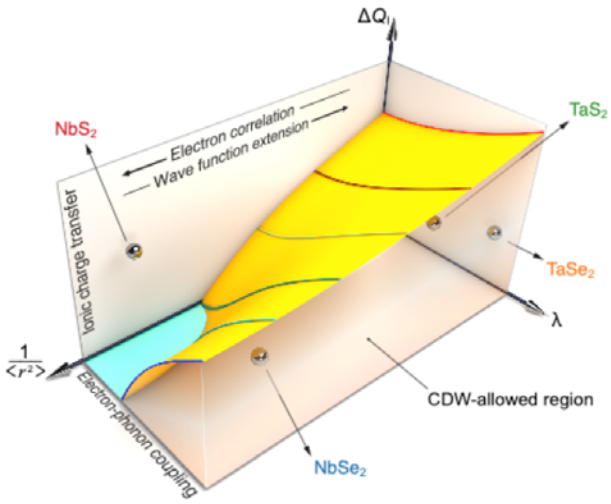


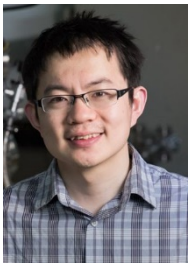
Figure 1. Schematic phase diagram describing the charge density wave order in a layered 2H-MX_2 compound in terms of ionic charge transfer ΔQ_I, electron-phonon coupling λ, and the spatial extension of electronic wave functions $1/<r^2>$.

[1] D. Lin, S. Li, J. Wen, H. Berger, L. Forró, H. Zhou, S. Jia, T. Taniguchi, K. Watanabe, X. Xi, M. S. Bahramy, Nature Communications **11**, 2406 (2020).

Invited speaker

5th International Workshop on 2D Materials

Title of the Presentation: Photoemission Study of Intrinsic Magnetic Topological Insulator $MnBi_2Te_4$ and $MnBi_4Te_7$



First Name: Zhongkai

Last Name: Liu

Affiliation: School of Physical Science and Technology,

Shanghaitech University, Shanghai, China

Email: liuzhk@shanghaitech.edu.cn

Short Biography: Zhongkai Liu received B.S. in physics from Tsinghua University and Ph. D in Stanford University under the supervision of Prof. Zhi-Xun Shen. After one year experience working as a postdoc in I05, DLS, he started as an assistant professor at ShanghaiTech University. His research interests lie in the photoemission study of topological quantum materials, low dimensional functional materials and development of synchrotron based spatial resolved ARPES.

Abstract:

Over the past years, topological insulators has attracted lots of research attentions due to their nontrivial topological electronic structure and important application potentials. With further inclusion of magnetism and breaking the important time-reversal symmetry, further interesting properties could be introduced, such as the quantum anomalous Hall effect and axion insulator. So far the magnetic topological insulators is only achieved in doped thin films with ultralow quantization temperature. Recently, the first intrinsic magnetic topological insulator, $MnBi_2Te_4$ has been proposed and quickly ignites intensive researches very recently.

In order to understand the exotic properties of $MnBi_2Te_4$ and explore its full potential, we systematically studied the subtle topological electronic structure of this promising material and its sister compound $MnBi_4Te_7$ using angle-resolved photoemission spectroscopy. Our results confirm the subtle topological nature of $MnBi_2Te_4$ that is modulated by magnetic ordering, which not only provides important insights into the generic understanding of the interplay between magnetism and topological electronic structure, but also pave the way for the design and realization of novel phenomena and applications.

[1] Y. J. Chen et al., Phys. Rev. X 9, 041040 (2019)

[2] L. X. Xu et al., arXiv: 1910.11014 (2019)

Invited speaker